Microsoft

Industry 4.0

Inside autonomous systems on the factory floor

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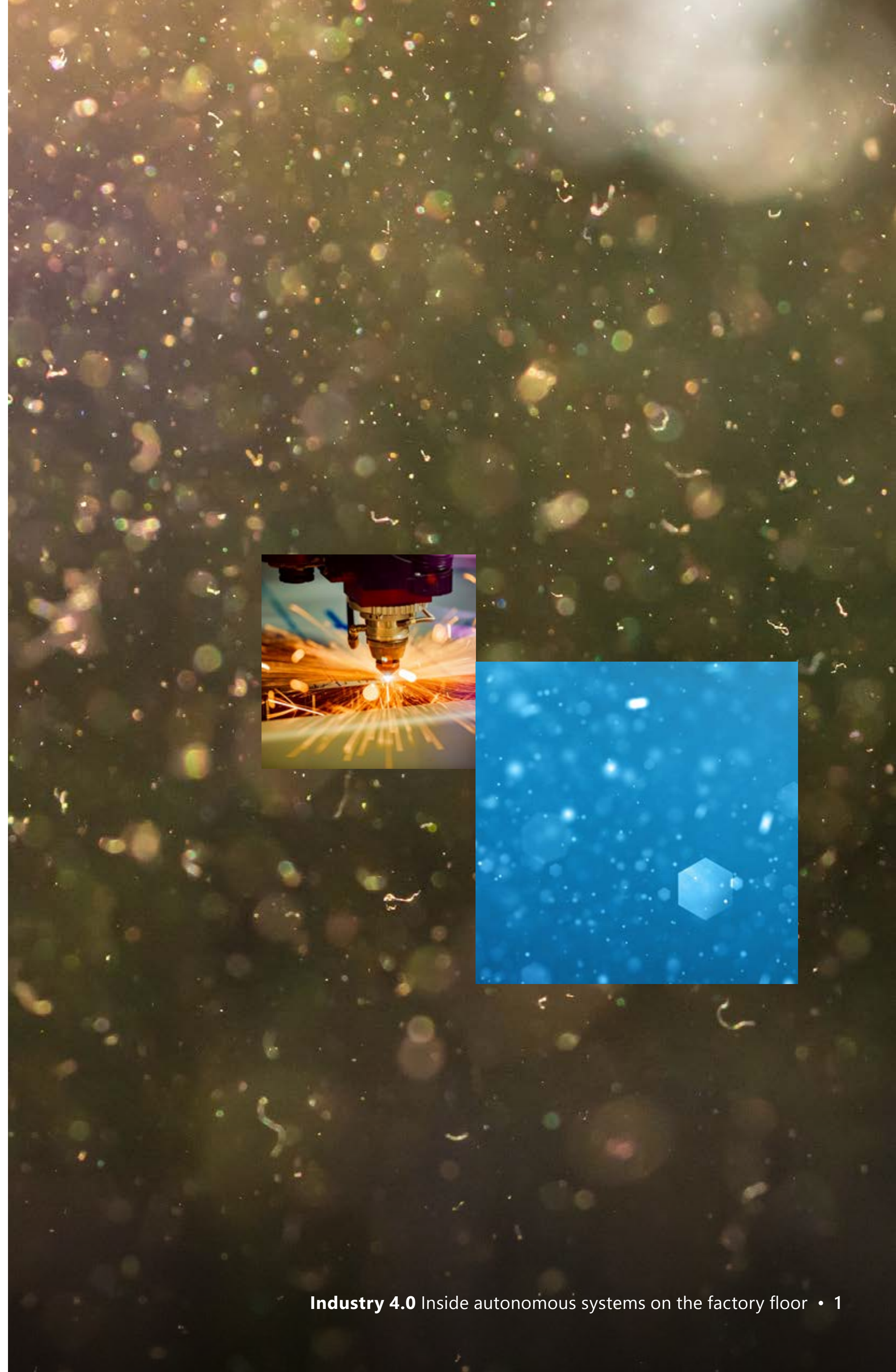


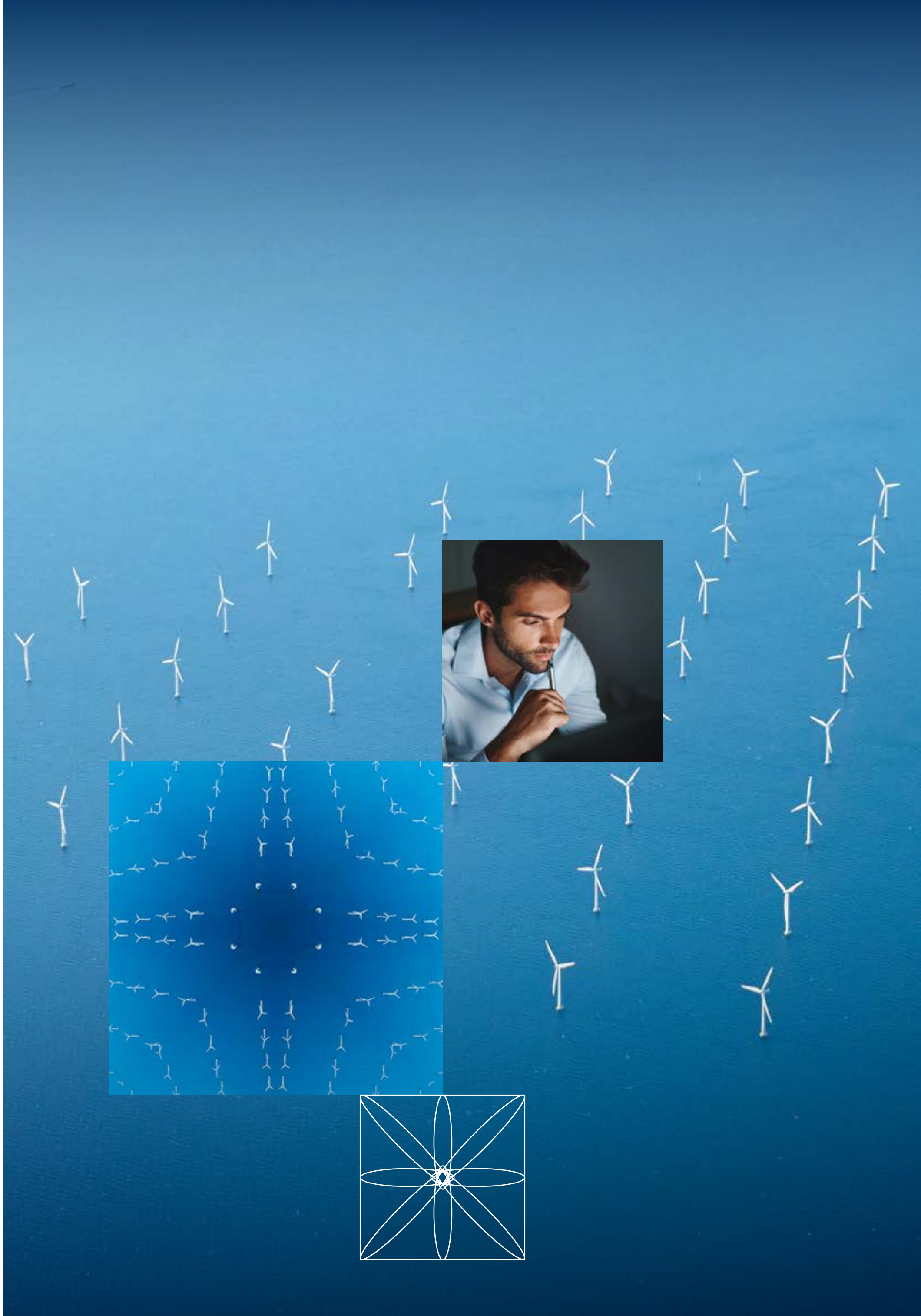
Preface

Throughout history, managing the factory environment during a pandemic has been a difficult task.

From Catherine the Great's exodus of Russian factories from Moscow in the early 1770s to modern manufacturers' increased emphasis on social distance and personal protective equipment, industry leaders have relied on drastic cultural and operational changes in order to protect their workers and maintain production.

Today, COVID-19 has forced industries worldwide into an era of adoption. In what seems like an instant, entire business lines have adopted remote operating tools, digital collaboration resources, and virtual working environments. This normalization of next-generation technologies has opened the eyes of many frontline workers and executives to the power of tools like artificial intelligence and cloud collaboration, and has whet their appetite for more tools.

For the modern manufacturer, autonomous systems represent that next step towards becoming a safer, productive, and innovative organization. Whether by scaling the wisdom of veteran workers or adapting key performance indicators to changes in supply chain, autonomy offers engineering leaders an avenue to continue operations without compromising on safety.



An introduction to the autonomous system

Autonomy comes with its share of assumptions.

At large, the concept of autonomy in technology tends to be linked with independence—a self-driving car, for instance, is a great example of an autonomous system, but one that is incredibly complex.

The most accessible autonomous system thrive in a smaller task, more readily controlled by human optimizers. At the core of the autonomous system, expertly trained AI complements human experience by recognizing and adapting to a variety of situations to make the best decision possible.

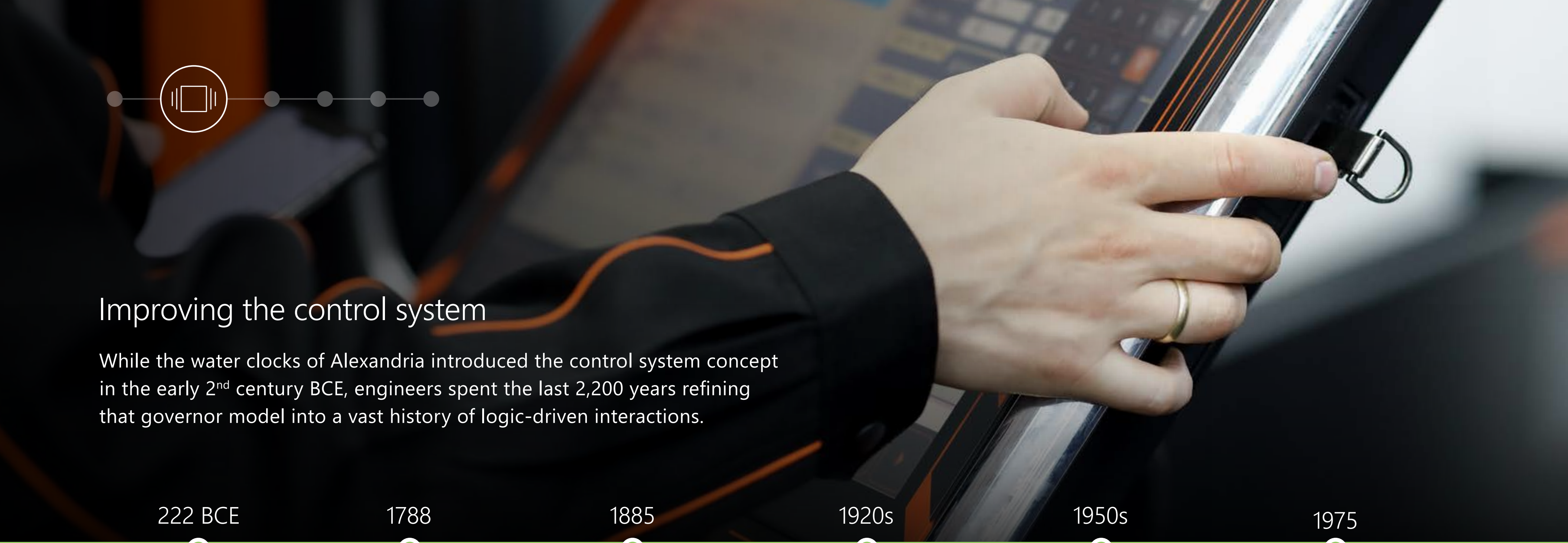
7 best practices for autonomous systems:

- Learn from human experts
- Can partner with humans to help with decision making
- Can be applied to a single component, a machine, or a full process
- Dictate and direct action like a traditional control system
- Learn and apply strategic best practices and safety policies
- Empower operators to make better decisions with AI-powered support
- Unlock efficiencies and optimize operations beyond human potential

By adding a layer of active education and human oversight, autonomous systems ascend beyond automation to become a scalable, intelligent system that learns to optimize even in the most complex scenarios.

Autonomous systems are designed to scale according to the need of the operation.

As such, their greatest impact starts when engineers identify a single control or process that would benefit from further optimization and grows incrementally, adding AI powered optimization by priority.



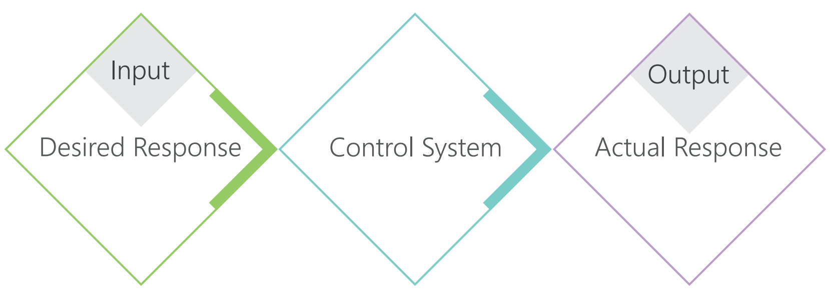
Improving the control system

While the water clocks of Alexandria introduced the control system concept in the early 2nd century BCE, engineers spent the last 2,200 years refining that governor model into a vast history of logic-driven interactions.

- 222 BCE — Ktesibios' Water Clock
- 1788 — Watt's Flyball Governor
- 1885 — Al Butz's Damper Flapper
- 1920s — Minorsky's Integral and Derivative Control
- 1950s — Kalman's Modern Control Methods
- 1975 — Programmable Language Controllers

At their core, control systems operate in a very simple manner:

The system receives an input with the desired response, processes that information, and delivers the actual response as an output.



This model has laid the foundation for decades of engineering innovations, starting with Watt's Flyball Governor in 1788 and culminating in stabilization, integral and derivative control, and other modern control methods established during the mid-20th century's Golden Age of Control. This era took what was initially a model of observations and reactions and expanded it into a computer-powered industry.

Every innovation amplifies the complexity of our inputs and quality of our outputs.

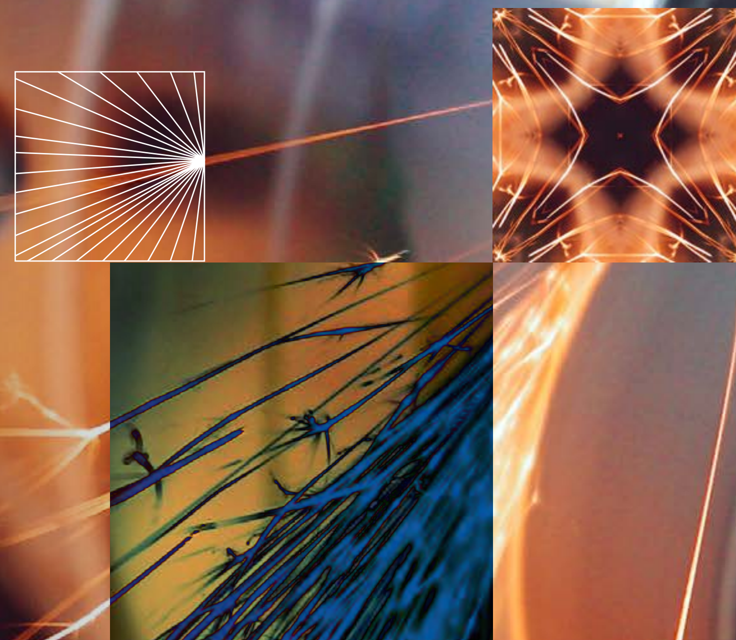
Now with the advances in AI and computers, the next iteration of control systems is available to engineers: autonomous systems. This evolution of open and closed loops continues to push the capabilities of our control models as engineers across generations strive to more closely align the actual response of their output with the desired response of their input.

Autonomous systems are simply the next step in that evolution. While traditional control systems are limited to a series of pre-existing setpoints, the intelligent system absorbs strategies and can identify the ideal conditions where those strategies ought to be deployed in order to help a human operator achieve their desired output. An autonomous system within a snack food manufacturer might recognize shifts in humidity and implement the best operational strategy to remain on course.

Autonomous systems elevate plant operations beyond automation and into true autonomy, opening up new possibilities for productivity and innovation.

The difference between automated and autonomous

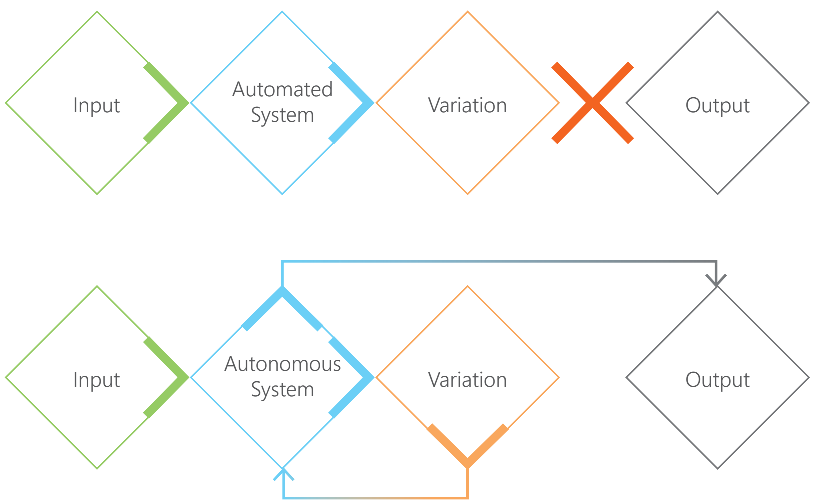
In recent decades, automation introduced facilities worldwide to the transformative power of technology in the workplace. While automation has defined the modern era of industry, automation and autonomy are not one and the same.

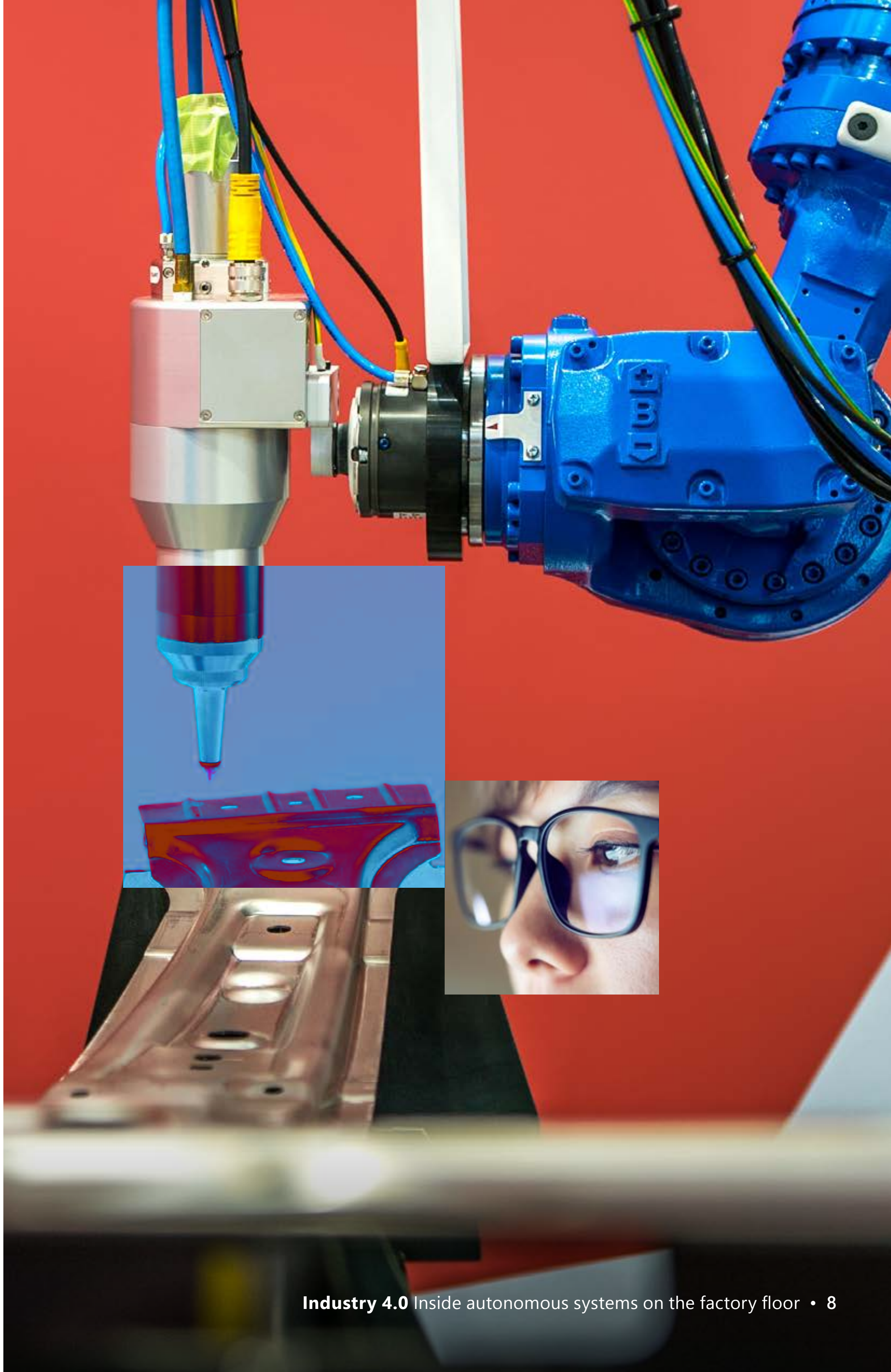


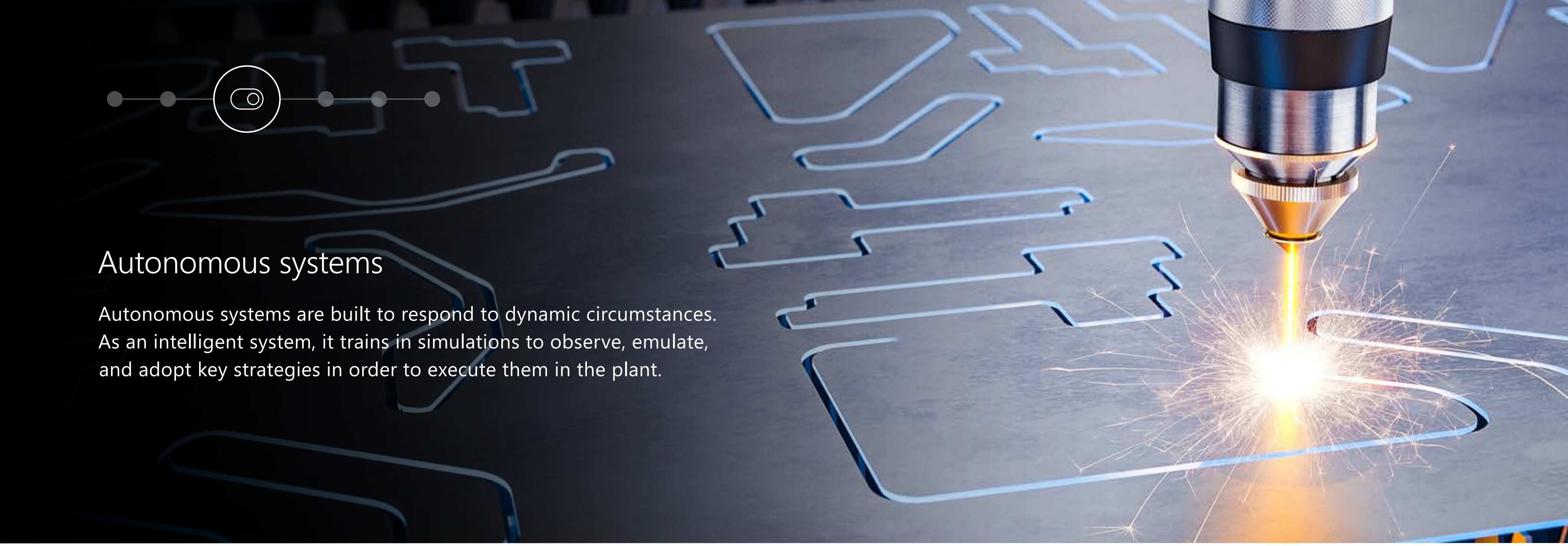
Industrial control systems, as we know them today, are built on **automation**; they rely on understanding how disparate inputs interact to affect expected outputs. Every process is programmed to execute a specific action. As a result, these systems are incredibly rigid. A CNC machine is programmed to cut a hole in a piece of steel that will one day become a car door. The automated system ensures that that machine will cut that same 2-inch hole every time with next to zero variations.

Assuming that car door is built to specs and placed perfectly on the line every single time, then the CNC executes its task perfectly every single time. But, if the door is placed slightly off-center, or the material is a few microns too thick, then the machine fails, and the process falls apart.

Automated systems tend to operate in black and white. Autonomous systems execute in more gray areas.







Autonomous systems

Autonomous systems are built to respond to dynamic circumstances. As an intelligent system, it trains in simulations to observe, emulate, and adopt key strategies in order to execute them in the plant.

This process allows the autonomous system to learn without disrupting operations or compromising safety. While an automated CNC would attempt to cut the 2-inch hole regardless of where the door was placed, the autonomous CNC would recognize when the door is off-center and adjust its cutting path accordingly.

In addition to adapting to changing variables, autonomous systems adapt to constantly changing optimization goals. From a functional perspective, factory operations teeter between complex and hierarchal objectives that occasionally conflict with one another. The ideal operation strategy for maximizing throughput likely isn't the most efficient process, while a methodology intended to maximize yield might not be the fastest.

Further, process variables influence the plant's production goals every day, be they supply, demand, weather conditions, staffing, supply chain, etc.

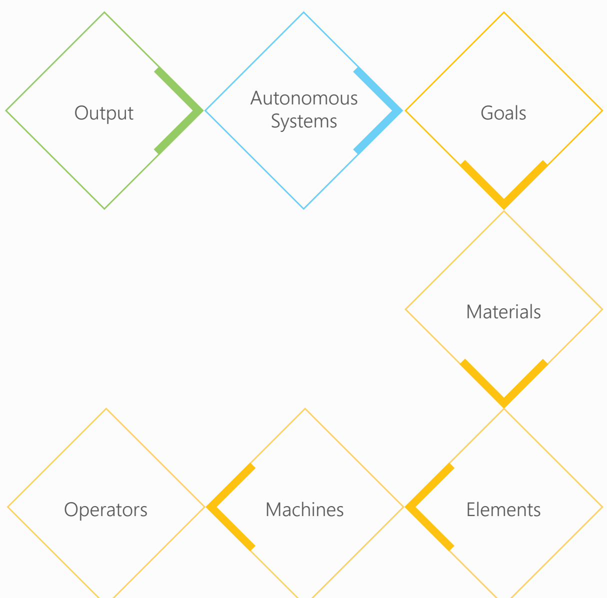
Traditionally, plants rely on the experience of systems and controls engineers to adapt the performance of an automated system to align factory conditions with those production goals. These experts bring a combination of both technical training and observational knowledge that positions them to recognize variable changes and adapt accordingly.

The autonomous system learns, from that same expert, to recognize process variables and make decisions based on the user-defined goals or even recommend its own objectives.

Autonomous systems can take that goal-centric performance a step further by making production goal recommendations based on current process variables. An autonomous system can analyze process variables and conditions across materials, elements, machines, and operators, then identify the best corresponding optimization area.

This ability to assess and analyze process variables at once allows autonomous systems to understand plant nuances that humans struggle to or simply cannot measure, calculate, or even recognize. For example, shifts in humidity or barometric pressure may influence site operations without human operators ever realizing there was a change.

Chemical engineers can't measure fouling, but they do understand that the slow blockage of pipes is a fundamental part of operating a plant. As systems age, seasoned engineers can identify key changes in performance as an indicator of a greater change within the system—output decreases because the flow of material is being restricted.



Until a measurement solution is implemented, organizations must rely on the intuition and wisdom of longtime workers. Experienced engineers use that wisdom to create a control strategy based on process variables, and shifting parameters, not all of which are directly measurable. These aren’t inputs that plants control; rather, they’re conditions that must be responded to.

While responding to these variables can take decades for a worker to do with high accuracy, an autonomous system can be taught what to look for and adapt accordingly to maintain production goals in a matter of weeks, days, and even hours.

How autonomy works

Autonomous systems combine compute scale, simulations, and new AI training methodologies to create a governing AI that learns and engages with the environment around it.

Trained by existing process experts, this AI learns the processes and strategies for a key optimization goal, then masters those skills in a simulated environment before executing them on the shop floor. This AI can work in tandem with humans or independently.

As the AI proves its mastery over the optimization, portions of the AI can then be reused to scale into other projects or optimizations that might benefit from autonomy.

This AI can work in tandem with humans or independently ›

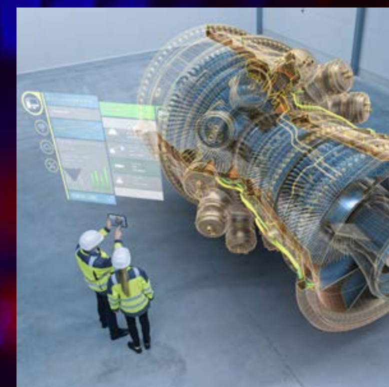
Humans and autonomous systems

Autonomous systems don't just amplify how plants perform under varying conditions; they also enhance our ability to empower their workforce.

Building autonomous systems doesn't require a team of data scientists—instead, best practices require the experts who are already familiar with the process variables today.

For complex systems and processes, it can take people years of familiarity and factory expertise developed over decades to be considered an expert. While experts age to retirement and new talent works to develop their own skills, organizations can lose decades of operational wisdom if it goes uncaptured.

Autonomous systems capture that institutional wisdom and pass it along to frontline workers to help them identify moments where advanced strategies can be applied safely. For example, under the right conditions, experienced plastic manufacturers can increase the temperature and pressure beyond the equipment's recommended rating in order to improve throughput—a strategy that, under other conditions, is incredibly dangerous. By teaching the AI to know the right time and place for a strategy like this, an autonomous system can recommend when to do so safely and consistently.



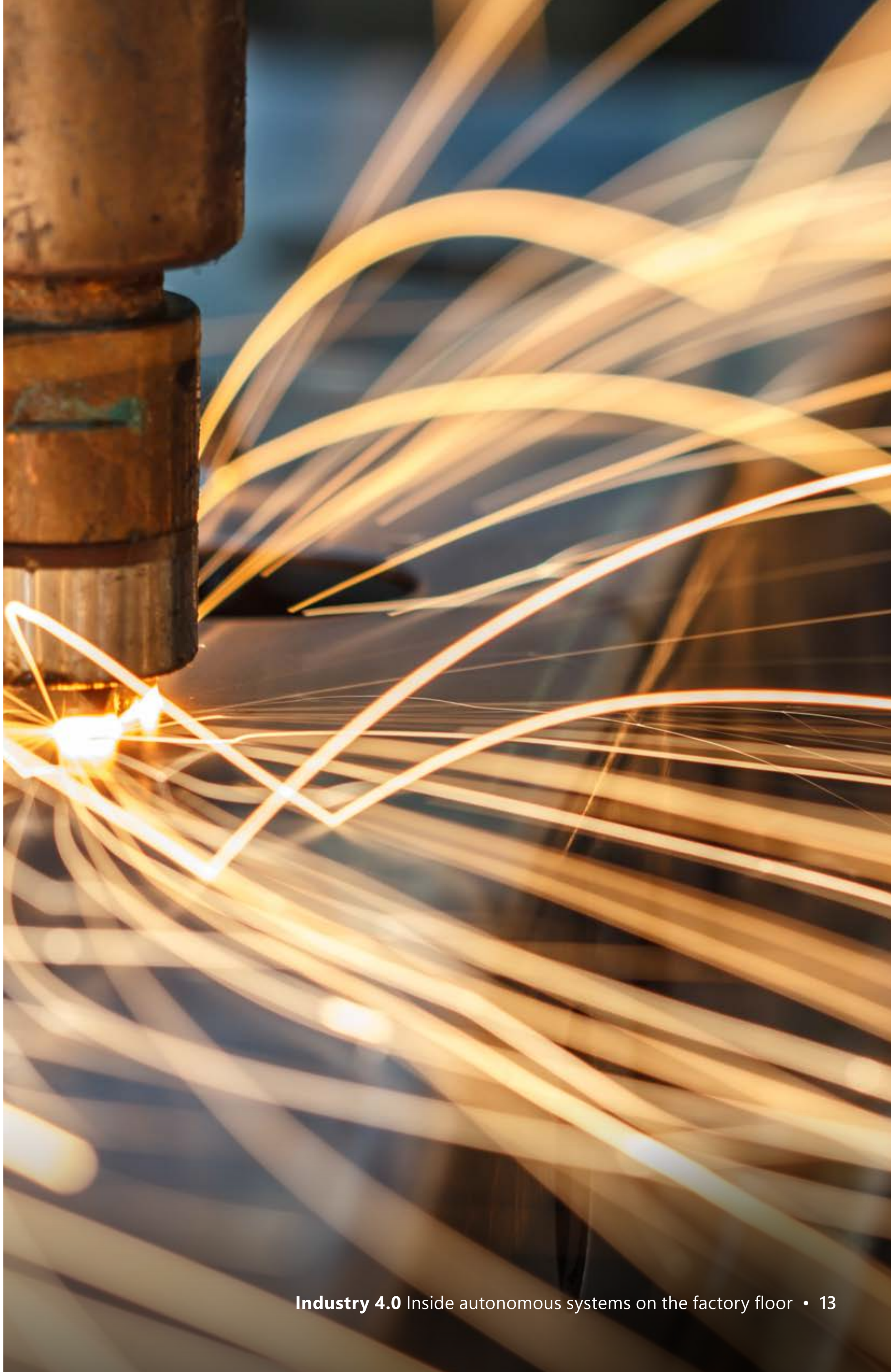
Even with the most experienced and reliable hands on deck, human error is still inevitable. The AI at the core of an autonomous system can consistently and efficiently manage thousands of inputs and anticipate how they interact with each other in a way even the most intelligent humans could never emulate.

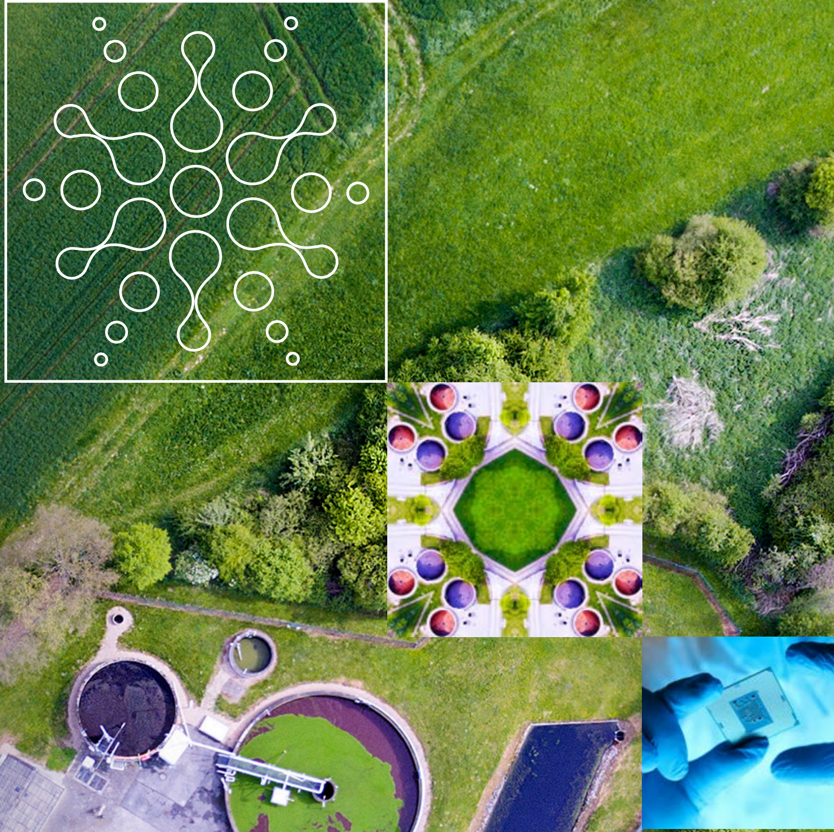
Likewise, no expert has the solution to every problem. As humans, every individual's knowledge base has its limits. While experts have the observational knowledge and technical training, autonomous systems merge the wisdom and knowledge of multiple experts with information learned through simulated scenarios to create optimal solutions.

This training method allows autonomous systems to identify control strategies for situations they never encountered in simulation that, while rare, may present expensive outcomes if not handled properly.

Ultimately, autonomous systems are designed to assist or advise human workers or function independently to optimize operations. Every plant is obligated to meet the goals of its stakeholders, and within that environment, every worker and operator is responsible for their transitions.

Autonomous systems can equip operators with best practices and recommendations or even extra attention to help reduce transition times and increase performance without sacrificing safety requirements.





Activating autonomy

Successful onboarding of an autonomous system requires the right foundation.

With these three elements in place, adding autonomous systems is a natural fit.

- **IoT** — Leverage the investments that you've already made in IoT or accelerate your investments in IoT.
- **Simulation** — Leverage and build on your simulation expertise and existing simulation models.
- **Human expertise** — Organize the disparate human expertise that you need to successfully build autonomous systems.

With those elements in place, it's important that operators don't overwhelm themselves in the process. Autonomy may seem daunting, but because operators choose where to adopt, starting with a single process variable gives factories a quick return on investment and builds the confidence required to scale the system to the next.

Introducing Microsoft Project Bonsai

Intelligent, autonomous systems learn to account for challenges like resource scarcity, managing fail-safe conditions, and adaptive object manipulation.

To accelerate this learning, Microsoft has pioneered a method that allows control and process experts to teach the AI using their own expertise. Microsoft Project Bonsai is a "low code" AI development platform that speeds the creation of AI-powered automation to improve production efficiency and reduce downtime.

Without requiring data scientists, engineers can build specific AI components that provide operator guidance or directly make decisions to optimize process variables.

The intuitive interface allows your engineers to create AI with their knowledge and experience without requiring additional resources. You get total control over how AI supports your operators—either working independently or in partnership with people—and total visibility into why decisions were made or recommended.

Want to learn more about autonomous systems?

Visit the ***Microsoft autonomous systems homepage*** ›

Want to learn more about optimizing your operations with AI?

Contact us ›

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